Association of farming practice and the seasonal occurrence of gastrointestinal helminths in a flock of sheep in Iceland

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ABSTRACT

Seasonal occurrence of gastrointestinal helminths was studied in ten replacement ewe lambs/young ewes in a flock of sheep in E Iceland from the round-up day 23 September 2002 until autumn of the next year, by performing faecal egg counts on 16 occasions. The lambs never received antiparasitic drugs. Five types of eggs were identified, corresponding to the four species *Moniezia expansa*, *Trichuris ovis*, *Nematodirus filicollis* and *N. spathiger*, as well as the group collectively known as "other strongyles", which in sheep in this part of Iceland are comprised of the species *Teladorsagia circumcincta*, *Trichostrongylus axei*, *T. capricola*, *T. vitrinus*, *Chabertia ovina* and *Oesophagostomum venulosum* (Richter 2002). The seasonal occurrence of the helminths was markedly influenced by the farm managing practice characterized by a short (one to two weeks) grazing period stay of sheep on home pastures after parturition in late May and a long summer grazing period at low stocking rates on mountainous rangelands. After herding back to the lowlands in late September, sheep are grazed on home pastures until housing in late autumn with hay feeding for approximately six months. Usually, the lambs acquired the *M. expansa*, *T. ovis*, *N. filicollis* and *N. spathiger* infections after their return to home pastures in September; consequently these infections peaked during late autumn and early winter. "Other strongyle" infections confirmed in the four-month old lambs in September, upon their return from the summer rangelands, were either acquired on the farm in spring or in the sparsely grazed summer rangelands. According to Richter (2002) *Teladorsagia* and *Trichostrongylus* predominate in the group "other strongyles". In general, worm egg counts in the present study revealed markedly lower values than reported in previous studies from Iceland. A distinct *M. expansa* egg excretion peak in late winter suggests that the cestode maintained its life cycle indoors on the farm.

Keywords: Sheep, gastrointestinal helminths, helminth egg counts, Iceland, seasonality

YFIRLIT

Tengsl búskaparhátta og árstíðasveiflu iðraorma í ásetningsgimbrum á Austfjörðum

Fylgst var með árstíðabreytingum iðraorma í tíu ásetningsgimbrum á sauðfjárbýli á Austurlandi frá réttardeginum 23. september 2002 fram í byrjun október næsta árs með því að telja ormaegg í saur í 16 skipti á tímabilinu. Lömbin fengu engin sníkjudýralyf. Greint var á milli fjögurra tegunda (mjólkurmaðksins *Moniezia expansa*, svipuormsins *Trichuris ovis* og flækjuormanna *Nematodirus filicollis* og *N. spathiger*). Eggjum annarra þráðorma, sem vitað er að hrjá sauðfé á austurhluta landsins (Richter 2002), (vinstrarormanna

Teladorsagia circumcincta og *Trichostrongylus axei,* smágirnistegundanna *T. capricola* og *T. vitrinus* og ristilormanna *Chabertia ovina* og *Oesophagostomum venulosum*) var slegið saman í hópinn "aðrir strongyle ormar" því ekki er hægt að greina milli tegundanna á útliti eggja. Skýr tengsl sáust milli árstíðabreytinga ormasýkinga og búskaparhátta á bænum en þeir einkenndust á þessum árum af stuttri (eins til tveggja vikna) viðdvöl fjár í heimahögum áður en sleppt var á dreifða, langvarandi beit í sumarhögum. Ekki var smalað og réttað á bænum fyrr en 23. september. Að haustinu gekk fé í heimahögum fram að hýsingu. Fóðrun stóð í rúma sex mánuði, fram yfir burð. Flestar ásetningsgimbrarnar smituðust fljótlega af *M. expansa*, *T. ovis*, *N. filicollis* og *N. spathiger* þegar haustbeit hófst í heimahögum og náði ormasmit í þeim hámarki síðla hausts og í vetrarbyrjun. Öðru máli gegndi um "aðra strongyle orma" sem gimbrarnar voru smitaðar af þegar þær komu af fjalli. Líklegt er að þær hafi náð í stærstan hluta þessa smits á fyrstu vikum ævinnar heima á bæ þótt einhver smitun sé einnig möguleg á dreifðri afréttarbeit. Í þessum hópi eru *Telodorsagia* og *Trichostrongylus* ormar algengastir (Richter 2002). Ormaeggjatölur í rannsókninni reyndust jafnan mun lægri en sést hefur í öðrum hérlendum rannsóknum. Greinilegur eggjatoppur í sumum gemlinganna síðla vetrar er vísbending um að mjólkurmaðkurinn geti lokið lífsferlinum innanhúss.

INTRODUCTION

In 2002 and 2003 gastrointestinal parasite infections were studied in a flock of replacement ewe lambs/young ewes *Ovis aries* L at the Fossárdalur farm in East Iceland On this farm lambs have suffered from severe diarrhoea in autumn and early winter, which sometimes has become fatal. Short term diarrhoea in a few lambs soon after their return from summer range in the highlands to their home pasture in the lowland in September or early October was regarded as caused by change in their diet. However, after approximately three weeks of grazing on home pastures all lambs got coccidiosis for one or more weeks, usually with severe diarrhoea and a typical weight loss (Skírnisson & Hansson 2006). Ten eimerid coccidian species were identified; *Eimeria ovinoidalis* McDougald, the most serious pathogen of the sheep eimerids (Eckert et al. 1995, Gregori 1989), predominated both during the coccidiosis phase in autumn as well as in other seasons of the year (Skírnisson 2007). In contradistinction to the eimerids, the commonly found *Entamoeba bovis* Liebetanz, recently also confirmed from reindeer *Rangifer tarandus* L in the area (Stensvold et al. 2010), and the rarely encountered *Cryptosporidium* sp. infections were not suspected of contributing to diarrhoea in the lambs (Skírnisson & Hansson 2006).

In this survey, seasonality of gastrointestinal helminth infections was also studied by performing faecal egg counts. Fourteen species are known to infect ruminants in Iceland; one cestode (*Moniezia expansa* Rudolphi) and 13 nematode species. The cestode parasitizes all four ruminants occurring on the island; sheep (Richter 2002), goats *Capra aegagrus hircus* Erxleben (Kristmundsson & Richter 2000), cattle *Bos taurus* L (Ingólfsson & Gíslason 1975) and reindeer (Gudmundsdóttir 2006, Skírnisson et al. 2006) and 11 of the 13 nematodes (*Bunostomum trigonocephalum* Rudolphi, *Chabertia ovina* Fabricius, *Cooperia onchophora* Railliet, *Nematodirus filicollis* Rudolphi, *N. spathiger* Railliet, *Oesophagostomum venulosum* Rudolphi, *Teladorsagia circumcincta* Stadelmann, *Trichostrongylus axei* Cobbold, *T. capricola* Ransom, *T. vitrinus* Loos, *Trichuris ovis* Abildgaard) infect sheep (Richter 2002). Various studies have shown that anthelmintic treatment of sheep improves growth and body conditions (Dýrmundsson et al. 1996, Richter 1974, 1976, Richter et al. 1983) and for this purpose various anthelmintics have been used in past decades, especially in areas with high grazing densities (Pálsson 1993).

In Fossárdalur the farming practice is as follows. From late autumn until parturition in late May (approximately half of the year) sheep are penned indoors and fed hay or silage. After parturition, ewes and newborn lambs are released on home pastures, usually only for one to two weeks, before being transferred to extensive summer rangelands around the farm. In the second half of September, sheep are gathered back to the lowland and kept on home pastures for approximately six weeks, usually until weather conditions demand housing. In comparison to other Icelandic sheep farms the farming practice in Fossárdalur is characterized by an exceptionally short stay on home pastures in the spring and an unusually long stay on sparsely grazed summer areas until early autumn. Although varying from one farm to another, sheep on other Icelandic farms are most often kept at high stocking rates for 3-4 weeks in spring, either on hayfields or home pastures around the farms. In summer high stocking rates are frequently observed especially if sheep are exclusively kept on the lowlands. In the autumn sheep are often collected from the summer rangelands to home pastures some weeks earlier than practiced at the Fossárdalur farm (Dýrmundsson et al. 1996, Gudmundsson & Dýrmundsson 1989).

The aim of the present study was to examine, by performing faecal worm egg counts, how the farming practice in Fossárdalur influenced gastrointestinal helminth infections in sheep on the farm. For this purpose 10 replacement ewe lambs/young ewes that had never received antiprotozoal or anthelmintic treatments were monitored for more than a year. The results are explained and compared to previous studies on gastrointestinal helminths of sheep in Iceland.

MATERIALS AND METHODS

Almost 500 winter-fed ewes are kept on the Fossárdalur farm (64°45'13.47 N, 14°31'03.81W). In 2002, sheep were gathered and driven back from the mountainous summer rangelands to the lowland on 23 September. On the round-up day 70 replacement ewe lambs were selected and grazed separately on an uncultivated lowland area adjacent to the farm until they were housed on 18 October. In the second half of May 2003 most of the one year old ewes gave birth to one lamb; a few bore two lambs. After parturition the young ewes were released with their lambs on cultivated home pasture temporarily grazed by the whole flock. One to two weeks later, in early June, the ten young mother ewes participating in the study (see below) were isolated from the flock and released with their lambs to a 400 ha pasture in the vicinity of the farm, where they grazed at a low stocking rate until 6 July, when they were moved to the summer rangelands (Gudný Gréta Eyjólfsdóttir and Haflidi Saevarsson, pers. comm.).

The lambs and anthelmintic treatment

On the round-up day (23 September 2002) ten of the replacement ewe lambs were randomly selected for a systematic study of their intestinal parasites. These lambs had never received any treatment against parasites, whereas the remaining 60 lambs in the group were given the anthelmintic Ivermectin (Oramec Drench vet) when first housed.

Sampling

Faecal samples for worm egg counts were collected on 16 occasions; first on the round-up day, 23 September 2002, four times in October (1^{st}, 13^{th}, 25^{th} and 29^{th}) and twice in November (11^{th} and 25^{th}) and then after that at the beginning of each month until July 2003. A final sampling was made on 3 October, shortly after the return of the flock to the lowland in the autumn of 2003.

Sampling was carried out by the farmers. Rectal faecal samples were taken wearing disposable gloves and placed in a wide, sterile 80 ml plastic container with a screw cap. Samples were sent overnight to the laboratory at Keldur, where they were refrigerated and examination usually followed in the next day or two.

Laboratory methods and identification

To obtain quantitative estimates on excretion of cestode (*M. expansa*) and nematode eggs samples were examined by the modified Mc Master method (Anonymous 1986, Rommel et al. 2000). Three grams of faeces were suspended in 87 ml of water (without removing coarse particles by sieving). After centrifugation, the supernatant was decanted and the

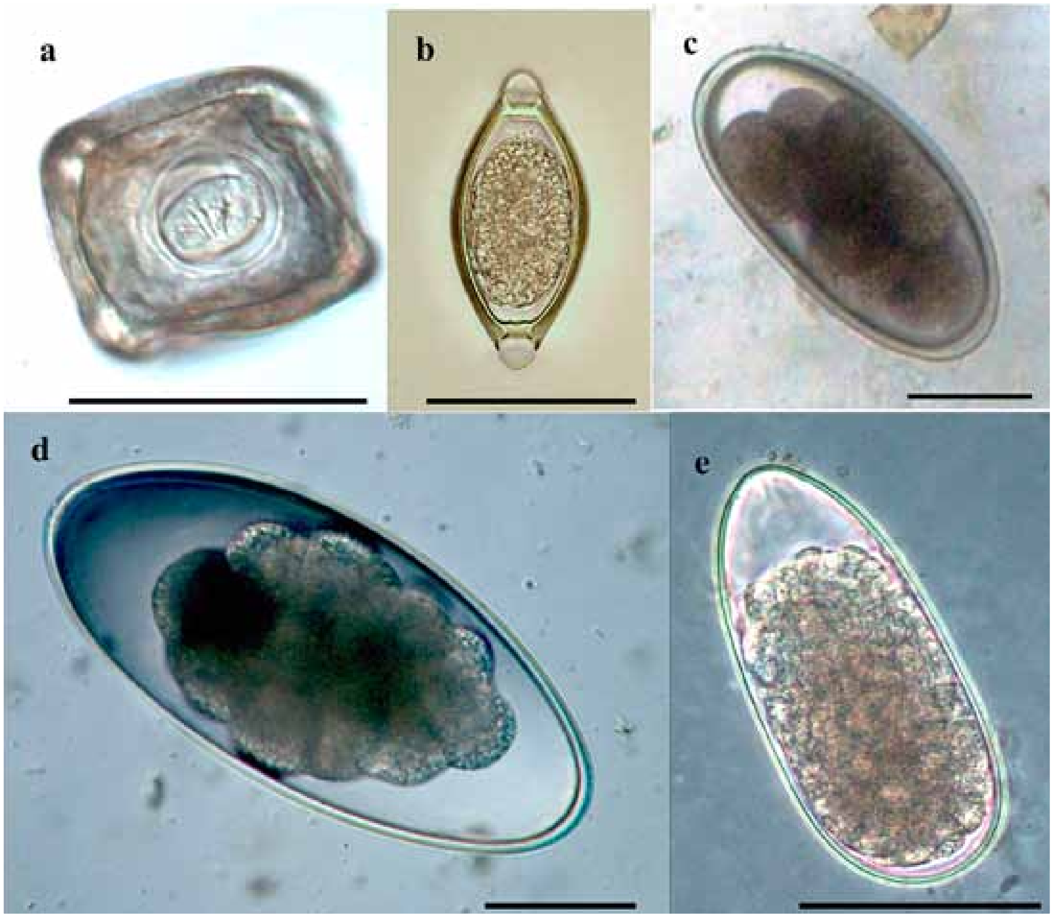

Figure 1. Light microscope photographs of gastrointestinal helminth egg types identified in faecal samples from sheep at the Fossárdalur farm in 2002-2003. **a** *Moniezia expansa*; **b** *Trichuris ovis*; **c** *Nematodirus filicollis*; **d** *N. spathiger*; **e** "Other strongyle" nematode eggs (includes *Chabertina ovina*, *Oesophagostomum venulosum*, *Teladorsagia circumcincta*, *Trichostrongylus axei*, *T. capricola* and *T. vitrinus*). *Scale bar* 50 µm

tube refilled with Parasitosol (specific density 1.27g/ml, Meku®, DK 7171, Denmark) to the same level. Four McMaster chambers (in two slides) were filled and 0.6 ml examined at 125x magnification under a microscope. Thus, the minimum detectable number was 50 eggs per gram faeces (epg). Based on distinct egg morphology (Figure 1), four helminth egg types could be distinguished to the species level; *M. expansa, T. ovis, N. filicollis* and *N. spathiger*. The fifth type of eggs belonged to a group of nematode worms referred to as "other strongyles", which are indistinguishable to the species level based on egg morphology. Nematodes belonging to this group and known to occur in ruminants in the eastern half of Iceland include *Teladorsagia circumcincta*, *Trichostrongylus axei*, *T. capricola*, *T. vitrinus*, *C. ovina* and *O. venulosum* (Richter 2002, Gudmundsdóttir 2006). Two other nematode species belonging to this group have been found in sheep in Iceland, *B. trigonocephalum* and *C. onchophora* but are not believed to occur in the eastern part of the country (Richter 2002).

Photographs
Photographs were made with a Leica DC 300 digital camera mounted on a Leitz microscope equipped with Nomarski (DIC) contrast.

RESULTS
Moniezia expansa
When herded back to the lowland on the round-up day, only one of the lambs examined was found positive for eggs from the cestode *M. expansa*. Later on in the autumn/early winter all the other lambs proved to be positive for eggs. Eggs were first detected in faeces from four of them on 21 October (28 days after the round-up day), in a further two on 29 October (36 days) and in the remaining three on 11 November (49 days), 25 November (62 days) and 8 December (76 days), respectively.

Most lambs (nine) were found to be infected (Figure 2), and the highest mean epg value (743; range 200 – 1,950), was recorded on 25 November (63 days after herding to the lowland, 37 days after housing). Two weeks later (8 December) the mean epg value had dropped to 383 (range 50 – 850); almost a month later (3 January) excretion of cestode eggs in faeces had stopped in all but one lamb (50 epg). In February, no eggs were detected in faeces. However, on 2 March, three lambs were found to be positive for eggs (mean epg value 250; range 150 – 450). No lambs were positive for eggs in the next two months but in May two of the three lambs that had started to excrete cestode eggs in March were still found to be positive for eggs, but only with 50 and 100 epg, respectively. When examined at 16 months of age, after returning to the lowland in October 2003, none of the animals were found to be positive for eggs.

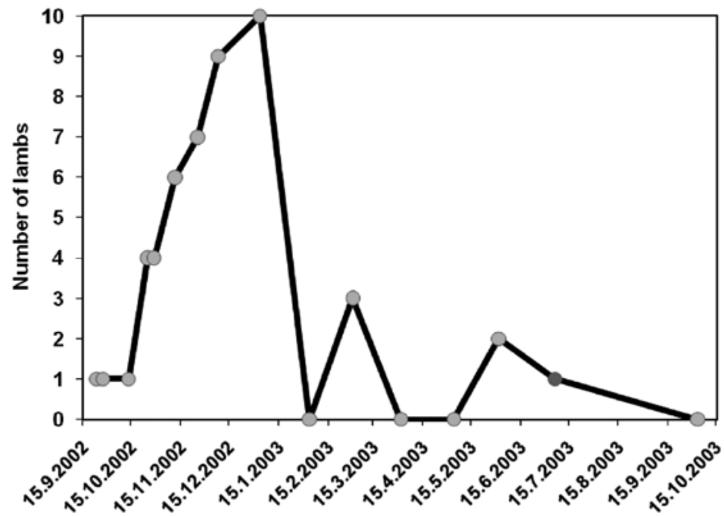

Figure 2. *Moniezia expansa* infections in 10 replacement ewe lambs/ young ewes at the Fossárdalur farm, E Iceland, studied for 12 months in 2002 and 2003.

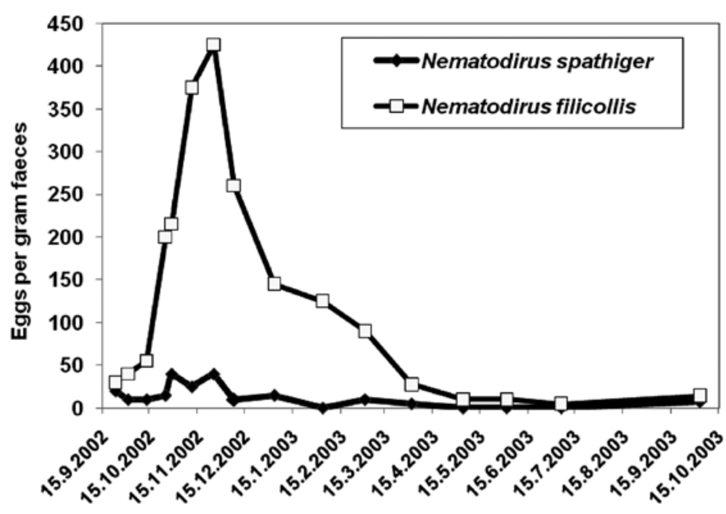

Figure 3. Mean numbers of *Nematodirus filicollis* and *N. spathiger* eggs per gram faeces (epg) in 10 replacement ewe lambs/young ewes at the Fossárdalur farm, E Iceland, studied for 12 months in 2002 and 2003.

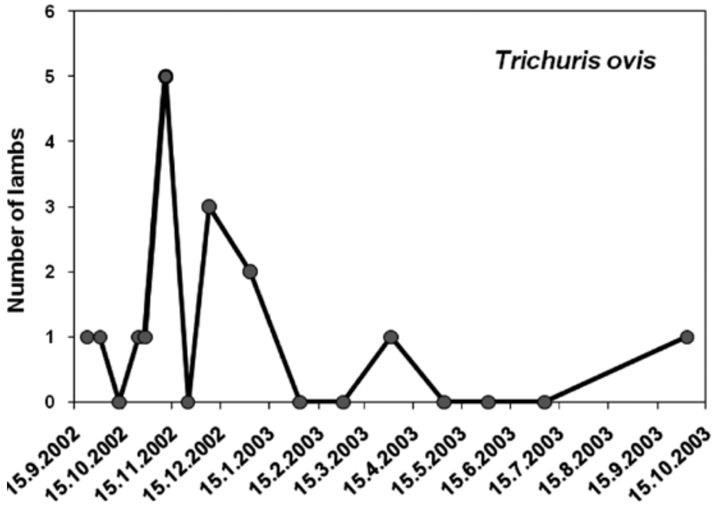

Figure 4. *Trichuris ovis* infections in 10 replacement ewe lambs/young ewes at the Fossárdalur farm, E Iceland, studied for 12 months in 2002 and 2003.

Nematodirus filicollis and *N. spathiger*

On the round-up day, *Nematodirus* infections were confirmed in four animals; three excreted both *N. filicollis* and *N. spathiger* eggs, whereas one lamb exclusively excreted eggs of *N. filicollis*. In the subsequent weeks, *N. filicollis* eggs were detected in faeces from all the remaining lambs (in three lambs on 1 October and in one lamb each on 13 October, 25 October and 29 October). By contrast, *N. spathiger* eggs were more rarely observed (Figure 3), and also later in the year (one lamb each on 1 October and 25 October, three lambs on 25 November, and in the last case eggs were not detected in faeces until 1 April); one lamb never proved to be infected.

Marked seasonal variation in egg output was observed for both species, although more clearly expressed for the more abundant species, *N. filicollis* (Figure 3). On average, there was a tenfold difference in egg counts between *N. filicollis* and *N. spathiger* in the survey. Maximum epg values were observed for both species in November. For *N. filicollis* the egg counts gradually increased throughout October, reaching a peak of 425 epg in late November, followed by a gradual decrease until late winter. The epg values re-mained low throughout the spring and summer, when at each sampling time only a single lamb excreted 50 or 100 eggs per gram of faeces, respectively.

Trichuris ovis

Trichuris ovis eggs were rarely encountered in faeces throughout the study period. Eggs were detected in 6 of the ten lambs during the study period and the mean epg value in positive lambs during the whole survey was 68 (range 50 – 150). The highest prevalence (five lambs) was recorded on 11 November, three lambs were found to be infected in December and two in early January. After that, only two sporadic cases (50 and 100 epg, respectively) were encountered until the end of the study period (Figure 4).

Other strongyles

The replacement ewe lambs arrived from the summer rangelands with an average egg count of “other strongyles” of 585 epg. This value gradually dropped in the following months and reached its lowest level in early March, when no eggs were found in faecal samples from four lambs and the remaining six lambs only had a mean epg value of 67 (range 50 – 100). The highest single epg value in the survey (1,600) was recorded in a lamb on 1 October; additional values that exceeded 1,000 epg were counted in September, November and July (Figure 5). A slight increase in “other strongyle” epg values was found in early April (mean value 60) and early May (110), but during the parturition period by the end of the month epg values increased in faecal samples from all the young mothers (mean epg 340, range 100-700). On 6 July, when ewes and lambs were released to the mountain pastures, a slightly lower “other strongyles” epg value (215) was found. However, at this time no infection with "other strongyles" was recorded in samples from four of the young ewes, and epg values of only 50 or 100 were revealed in four others, whereas the remaining two young ewes showed a distinct rise in faecal egg excretion (800 and 1,100 epg, respectively). After returning to the lowland in the autumn of 2003, slightly lower mean epg values (457; range 0 – 1,000) were recorded than on the round-up day in the year before when these animals were four months old (Figure 5).

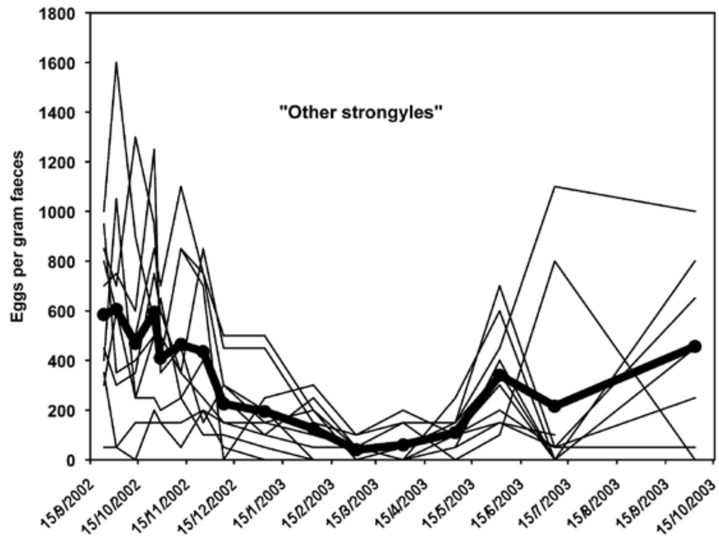

Figure 5. Seasonal variation of "other strongyle" eggs per gram faeces in 10 replacement ewe lambs/young ewes at the Fossárdalur farm studied for 12 months in 2002 and 2003. Mean epg values expressed as bold line, individual infections expressed as thin lines.

DISCUSSION

Comparison of the results for sheep parasites obtained in the present study to those in other surveys in Iceland showed some marked differences. Firstly, the farming practice in Fossárdalur seems to contribute to a lower level of gastrointestinal helminth infections than observed at greater stocking rates where sheep are kept under more crowded conditions on home pastures during the warmest months of the year (Gíslason 1968, Richter 1974, Richter 1976, Richter et al. 1983, Richter 2004). Secondly, the farming practice also determines the time of year when helminths infect sheep. On the Fossárdalur farm infections by *Moniezia expansa, Nematodirus filicollis, N. spathiger* and *Trichuris ovis* were more or less postponed until autumn. However, in September, when the sheep had been herded back to the contaminated home fields, infections were rapidly acquired. Consequently, helminth infections appeared in Fossárdalur several weeks or even months later than reported in all other surveys performed in Iceland (Gíslason 1968, Richter 1974, Richter 1976, Richter et al. 1983, Richter 2004). Thirdly, the somewhat inconspicuous spring epg rise in lambs on the Fossárdalur farm was markedly less prominent and appeared at least one month later than described in the only other comparable study from Iceland, a survey carried out at Gestshús in West Iceland during 1971 to 1973 (Richter 1974).

Moniezia expansa

The tapeworm *Moniezia expansa* lives in the small intestine of several ruminant species (Lapage 1968, Schnieder 2000, Soulsby 1968, Urquhart et al. 2007). The life cycle involves an intermediate host. Eggs, each containing an infective onchosphere, are passed on through the faeces, either singly or in gravid segments, and may remain viable on pasture for up to one month (Soulsby 1968). Eggs are swallowed by free living mites belonging to the family Oribatidae, and the onchosphere develops within the mite to the cysticercoid stage. The mites are long-lived and can survive up to two years (Schnieder 2000). Environmental temperature markedly influences the developmental time of the cysticercoid. According to Soulsby (1968) almost seven months are needed for this process at 16°C in the UK. However, in central

Europe Schnieder (2000) reports that cysticercoids can develop during the three warm summer months. The final host acquires the infection by accidentally ingesting infected mites, usually when grazing the pasture. Oribatid mites are commonly found in Iceland (Gjelstrup & Solhøy 1994). Mature *M. expansa* segments containing fertilized eggs may appear in faeces 30 to 52 days post-infection (Schnieder 2000), whereas Soulsby (1968) reports a shorter prepatent period of 37 to 40 days. The longevity of the cestode may vary from two to six months (Soulsby 1968), but Schnieder (2000) and Urquehart et al. (2007) report three months to be the usual patent period.

As *M. expansa* eggs are usually kept within segments that are irregularly shed and only mix with faecal matter when segments rupture, there is not a direct correlation between the presence of *M. expansa* eggs in faeces and infection intensities. Therefore, conclusions on the seasonal abundance and intensity of infections in sheep at the Fossárdalur farm must be treated with caution, especially at low infection levels when the parasite might have remained undetected. Thus, only one of the ten lambs was found to be positive for eggs on the round-up day. This lamb presumably acquired the infection from infected mites on home pastures in late spring, although infections in the mountainous pastures during summer should not be excluded despite the low stocking rates. Other lambs presumably acquired the infection in early autumn, most of them probably after being herded back to home pastures on 23 September. However, lambs that were already excreting eggs 28 days after the round-up day might have acquired the infection somewhat earlier in September, given that the prepatent period in Iceland is not a few days shorter than the minimum prepatent period (30 days) reported by Schnieder (2002). Such infections are possible because some ewes (together with their lambs) often return to the lowland on their own in early September, or even in August, where seasonal crowding may promote helminth infections prior to the round-up day.

The nine lambs that are regarded to have acquired their *M. expansa* infections on the lowland in the autumn excreted cestode eggs for 74 days (from 21 October to 3 January), thus indicating a patent period (egg production phase of adult worms) of approximately 10-11 weeks. During this period the highest egg output in individual samples was reported on November 25 (743 epg) and December 8 (383), five and seven weeks after worms had started producing eggs. Compared to the reported patent period of the tapeworm (Urquehart et al. 2007, Soulsby 1968), the patent period in lambs in Fossárdalur seems to be quite similar or even somewhat shorter.

M. expansa egg production mainly occurred in lambs at Fossárdalur in the autumn. Due to their short viability, eggs must be eaten within a month by an oribatid mite in order to survive the winter. However, the long developmental time of the larvae in mites under the cold winter and spring weather conditions in Iceland is thought to hinder maturity of the cysticercoid until the following summer, after the sheep have already left the home pastures. In the autumn, however, the cysticercoids should have reached maturity. Rare spring infections encountered in lambs on the farm probably originated from infective mites that had survived two winters on home pastures. Thus, the farming practice, the cold weather conditions and a long developmental time of the cysticercoid seem to explain why *M. expansa* infections mainly occurred in sheep in the autumn in Fossárdalur. Other studies in Iceland report comparable results, although mature *M. expansa* have been noticed in lambs in other flocks in September (Richter 2002, Richter et al. 1983), at least a month earlier than eggs started to appear in the faeces of most lambs in Fossárdalur.

The small *M. expansa* peak in epg observed in March might indicate that the cestode successfully completed its life cycle in the sheep barn. Abroad, the life cycle of *M. expansa* is known to be maintained indoors, where oribatid mites survive in hay or straw litter (Schnieder 2000). Oribatid mites have been found in Iceland in hay dust and dry plant material that accumulates below the wooden hay troughs (Skirnisson, unpublished) and are also common outdoors in various habitats (Gjelstrup & Solhøy 1994). As shown in the present study, large numbers of eggs (up to 1,250 eggs per gram) occurred in the faeces of the lambs in early winter. Therefore, conditions for the successful maintenance of the life cycle are met within Icelandic sheep barns. It remains unknown, however, whether these long-lived mites that might have acted as a source of infection while the sheep were housed in the barn ate ripe eggs eggs in the previous autumn or even in the year before.

Nematodirus spp.

Infective larvae (L3) of the *Nematodirus* species develop within the egg shell. The development time is slow; in temperate climates it takes at least two months. Once the L3 is present, there is often a lag period before hatching occurs and the infective larva is released (Urquehart et al. 2007). When released, the larvae are resistant to adverse climatic conditions, such as freezing and drying, and may survive in faeces for longer than a year (Lapage 1968). These life cycle peculiarities determine that eggs deposited on home pastures in autumn and early winter will not develop to the infective L3 until the following summer, actually at the time of year when the sheep on the Fossárdalur farm have already left home pastures. However, in autumn infections are soon acquired, and after a short prepatent period (two or three weeks) mature worms start laying eggs (Figure 3). The infection pattern observed on the farm can thus be explained by the slow development time of the larval stage.

Nematodiriosis is primarily a disease of young sheep that will have developed almost a complete resistance by one year of age. If the initial infection is sufficient, lambs develop immunity that causes the elimination of *Nematodirus* within four to seven weeks (Schnieder 2000). In Fossárdalur the pattern of infection (Figure 3) indicated that a parasite-specific immune response started to eliminate worms in late November or December; four months later (March), egg production had more or less stopped. After that, until the end of the study period, only sporadic and light infections (epg values 50 or 100) were registered. Based on different epg values observed for the two species, the pattern of infection was markedly clearer for *N. filicollis*. Earlier Icelandic studies have also shown *N. filicollis* infections to be much more common than those of *N. spathiger*. Thus, Richter (2002) reported that 76% of *Nematodirus* worms identified in a study on 94 slaughter lambs from various parts of Iceland were *N. filicollis*. Similarly, Gíslason (1968) showed this proportion to be 94% in 10 lambs kept on home pastures at the Hestur farm in West Iceland. Parasitological studies on the same farm in 1981 showed that 90% of *Nematodirus* eggs in lambs grazing on aftermath in the autumn were *N. filicollis* (Richter et al 1983). Exactly the same proportional value was reported in the present study.

In comparison to results obtained in the present study, Richter (1974) observed a quite similar seasonal pattern of infection in lambs that grazed in highland areas during the summer and had obviously acquired the infection after their return to the lowland. However, Gíslason (1968) reported light infections of both species as early as 11 August in lambs that had been kept on home pastures throughout the summer; on 2 October *Nematodirus* spp. worms dominated over other nematodes found in the flock, with more than 7000 worms per lamb. In this case, *Nematodirus* infections obviously had developed some weeks earlier than observed in the present study.

In Canada it has been shown to be common that lambs kept indoors or in dry lots can become infected by *Nematodirus*, indicating that the parasite can complete its life cycle without pasturing (Anonymous 2010). Whether this is the case in Fossárdalur is unknown. However, the bulk of *Nematodirus* eggs produced in the present study were deposited indoors after penning of the replacement ewe lambs.

Trichuris ovis

The infective stage in the life cycle of *Trichuris ovis* is L1 within the egg, which, depending on the temperature, develops in one or two months after being passed in faeces. Under optimal conditions these may subsequently survive for up to four years. After ingestion, hatched L1 penetrate the glands of the caecal mucosa to moult (Anonymous 2010, Urquhart et al. 2007). The prepatent period is 53-55 days (Schnieder 2000).

In the present study, light infections were observed in 60% of the replacement ewe lambs. Richter (2002) reported a somewhat lower (35.1%) prevalence of infection from late September and early October. One of the lambs arrived infected from the summer rangelands. Whether it acquired the infection on home pastures in spring, in the sparsely grazed summer rangelands, or on lowland somewhat prior to the round-up day is unknown.

"Other strongyles"

As already noticed, *Teladorsagia* and *Trichostrongylus* nematodes form the bulk of the group "other strongyles" (Richter 2002). As in other strongyles, the life cycle of *Teladorsagia* involves both a free-living and a parasitic phase. In the free-living phase, *Teladorsagia* eggs develop in the faeces to the infective third stage larvae (L3) within two weeks under optimal conditions. Under moist conditions, the L3 migrate from the faeces onto the herbage. The parasitic phase starts with the ingestion of L3. After two moults the nematode becomes sexually mature on the mucosal surface of the abomasum. Usually the parasitic life cycle takes three weeks to reach patency. Under certain circumstances (Urquhart et al. 2007) many of the ingested L3 become arrested in development at the early fourth larval stage for a period of up to six months. In spring, the arrested stage in the abomasum develops to maturity and starts to contribute to egg contamination of pastures. This periparturient rise in egg output is also named spring rise (Anonymous 2010). The life cycle of *Trichostrongylus* is similar; development from the egg to the infective stage occurs in 1-2 weeks on pasture under favourable conditions. Immunity to *Teladorsagia* and *Trichostrongylus* is acquired slowly and wanes during the periparturient period (Urquhart et al. 2007).

Upon arrival from the summer rangelands all lambs in Fossárdalur were infected by "other strongyles", parasites that were presumably mainly acquired on home pastures in spring before the lambs were released to the summer rangelands. Such early infections are known from other studies. Richter (1974) detected "other strongyle" eggs in five week old lambs that must have acquired the infection in their first or second week of age. Some of the "other strongyle" infections, however, may have been acquired during summer grazing.

"Other strongyle" epg values observed in sheep in Fossárdalur on the round-up day in late September (mean value, 585 epg) were less than half the numbers reported at the same time of the year in two other studies performed in W Iceland. One of the studies was carried out on the Hestur farm on 24 September (mean epg value in 24 lambs 1,304 epg, SD±712; Richter et al. 1983), the other study at the Korpúlfsstadir farm, where total epg values in six lambs never treated with anthelmintica increased from early July until 2 October from approximately 900 to 1,420 epg (Gíslason 1968).

Slowly increasing immunity gradually removes "other strongyle" infections from autumn until mid-winter (Schnieder 2000, Urquhart et al. 2007). The same tendency was observed in the egg excretion pattern in the present study (Figure 5). Comparable results were obtained by the examination of four lambs during the autumn and winter in 1972 at the Gestshús farm in W Iceland (Richter 1974).

Spring egg rise is usually observed when immunity wanes prior to and during the periparturient period (Soulsby 1968, Schnieder 2000). In the present study no marked spring rise had occurred on 4 May (mean epg 110, range 0-250); however, three weeks later (25 May) egg excretion had increased (340 epg, range 100-700). The study at Gestshús recorded values during the parturient period that were almost twice as high (average epg value 668, SD±441, range 50-1,500, n=4; Richter 1974).

The almost complete absence of "other strongyle" eggs on 6 July in most (80%) of the young ewes in Fossárdalur suggests that they had not been exposed to marked L3 contamination in the vicinity of the farm in late May and early June. However, considering the 18-day-long prepatent period (Schnieder 2000), recent infections could still have been developing. Quite high epg values in two of these young ewes confirmed that some individuals had been exposed to infective larvae on home pastures in Fossárdalur.

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